

Gene action and parental performance for some quantitative traits in maize

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Abstract

The present investigation was carried out to evaluate combining ability effects for grain yield and various yield contributing components in eight elite maize S₄ lines. Analysis of variances revealed that cross combinations were 17-75 % superior as compared to parental genotypes for all the studied parameters. Components of variation due to specific combining ability were greater in magnitude and more significant for all the characters excluding ear per plant and kernel rows per ear as compared to variance due to general combining ability. This revealed that the inheritance of these traits were controlled by non-additive type of gene action and recommended that selection of the genotypes might be effective for genetic improvement of all the traits in the advanced generation except for kernel rows per ear. It was also recommended from the relative general and specific combining ability performances that parental lines (SY-204 and IQ-207) and direct cross (PH-203 × SW-206) was better in grain yield per plant and might be helpful if exploited in future maize development programs.

Keywords: Combining ability, gene action, non-additive, maize, grain yield

Introduction

Maize is an important cereal crop of the world. Maize crop is widely cultivated throughout the globe and has the highest production among all the cereals. According to FAO (2017) [9] worldwide maize production was recorded 1046 million tones. During 2017-18 in Pakistan, maize grown-up on an area of 1229 thousand hectare with total production of 5.702 million tones (PBS 2017-18) [18] with average yield of 4640 kg per hectare. Maize kernels contain precious amount of nutrients like protein (10.4 %), fat (4.5 %), starch (71.8 %) and other essential raw materials like magnesium (Mg), phosphorus (P), iron (Fe) and sulphur (S) Nawab *et al.*, (1999) [15]. Maize crop is good support for manufacturing raw materials for the production of edible oil, polymeric carbohydrates, elastic proteins, alcohol, simple sugar and many additional products. Maize crop has several factors which lead to limitation in boosting production to fulfill the growing demand. Limiting factors to maize production are biotic and abiotic factors, in biotic stress mainly drought and heat stress which cause hindrance to achieve the maximum production of maize crop especially in those growing areas where temperature raises in growing season like in Pakistan. Under the changed climatic condition breeders should genuinely be interested in the development of hybrids, which are superior production. Development of hybrids depends upon the selection of superior parents, technical skill and professional competence. High production per unit area is the basic objective in maize breeding program. The development of promising genotypes to be used in the improvement of a crop is very important, as it is necessary to parental lines. Diallel mating design is one of the most valuable designs for evaluating genetic material in a crop population which is achieved with the help of evaluation of GCA and SCA effects. A genotype performance is associated to the GCA and SCA effects of the parents concerned to a particular hybrid development (Sprague and Tatum, 1942) [19]. Diallel analysis method has been

practiced widely to assess genotypes for their general combining ability and specific combining ability effects. The exploration of combining abilities provides circumstances to eliminate objectionable genotypes and decide on the mainly enviable ones to comprise a choice of hybrid development i.e., single crosses, dual crosses, synthetic and composite varieties (Griffing's 1956) [10]. The research work was designed with a view to estimate the different components of variation due to combining ability effects for some quantitative traits.

Material and Methods

The experiment was conducted at Research Area of Faculty of Agriculture, Gomal University, Dera Ismail Khan, Khyber PakhtunKhwā, Pakistan during the year 2016-17. The investigational materials were consisted eight maize (S₄) lines, such as SY-200, A-201, SW-202, PH-203, SY-204, JL-205, SW-206 and IQ-207. These inbred lines were hybridized in a full diallel mating scheme to produce F₁'s hybrids. All the F₁'s hybrids along with their parents were evaluated in the spring season 2017, using a randomized complete block design with 3 replications; plot length was 5m long within row spacing of 75cm as well as plant to plant spacing was kept 20cm equally. Recommended agronomic practices were applied to all the entries. Five plants were randomly selected for collecting of every plot for the entire attributes under investigation. Average of five plants for every plot in all replication was worked out for each attributes and was further analyzed. The data were recorded for plant height, flag leaf area (cm²), number of ears per plant, number of kernel rows per ear, number of kernel per row, 100-kernel weight and grain yield per plant (g). The data consisted of different parameters under investigation were arithmetically assessed by the typical analysis of variation method as described by steel *et al.*, (1997) [20]. Than additional assessment was done by mean of diallel mating procedure for scrutiny of general, specific and

reciprocal effects with the help of Griffing's (1956) ^[10] method-1, model-1.

Results and Discussion

Investigations of components of variations were portioned into general combining ability, specific combining ability and reciprocal effects as shown in (Table 1). Mean squares for general combining ability were highly significant for all the traits under investigation. Mean squares for specific combining ability as well as for reciprocal effects were also highly significant for all the studied characters. Significant mean squares of general and specific combining ability

showed that inheritance of these traits were under the control of additive type of gene action. Taufiq and Ijaz (2016) ^[21] suggested the importance of inheritance of additive and non additive genetic effects for plant height. Cross combinations results (Table 1) showed better performance than parents for all the characters under investigation. Andeera *et al.*, (2019) ^[3] also reported that the additive genetic effects were mostly concerned in the inheritance of traits like kernel per row, kernel rows per ear and 100-kernel weight.

Table 1: Mean squares for general, specific and reciprocal effects for some quantitative traits in maize

SOV	df	Plant height (cm)	Leaf area (cm ²)	Ears per Plant	Kernel rows per ear	No. of kernels per row	100-kernel weight (g)	Grain yield per plant (g)
Gca	7	175.19**	5414.86**	2.10**	25.98**	1.23**	12.55**	3103.34**
Sca	28	242.94**	3092.32**	0.01**	9.29**	1.22**	9.17**	1599.63**
Reciprocal	28	83.53**	1527.04**	6.68**	4.29**	0.63**	2.58**	359.26**
Error	126	15.05	680.41	6.60	2.55	0.46	1.24	21.91
Gca/gca+sca		0.42	0.64	0.99	0.74	0.66	0.58	0.66

Combining ability effects for some polygenic traits

Assessment of genetic diversity among maize genotypes (Table 2) showed that two inbred lines had good general combining ability effects in case of plant height, SY-200 showed good general combining ability with the value of (5.31), whereas the inbred line IQ-207 had poor general combining ability effect with value of (-4.27), was recognized as poor combiner. Among the crosses positive specific combining ability were displayed by twenty cross combinations. AZ-201× SW-206 (13.65), SY-204× JL-205 (8.89) was followed by SY-200× AZ-201 (7.87) were the useful specific combinations for their positive effects. While the cross SW-202× SY-204 with negative value (-6.13) was found poor (Table 3). Seventeen crosses showed positive reciprocal effects, highest (12.66) for SW-206× IQ-207 and IQ-207× AZ-201 (11.98) whereas negative reciprocal effects were displayed by eleven crosses, PH-203× AZ-201 (Table 4) had poor performance with negative value of (-13.65). The results were in accordance to various research workers in maize (Chung *et al.*, 2006; Alam *et al.*, 2013 and Neha *et al.*, 2018) ^[1, 7, 17]. Calculation of combining ability effects (Table 2) presents that five parents had positive general combining ability results with highest SW-202 (20.11) which was decided the good general combiner for leaf area. The inbred line JL-205 has the highest (-37.01) negative general combining ability result. For leaf area (Table 3) direct cross SY-200× SY-204 expressed highest specific combining ability (48.80), while direct cross PH-203× JL-205 had poor specific combining ability effect with value of (-62.84). For leaf area twenty one crosses had showed desirable reciprocal results; cross AZ-201× JL-205 showed maximum positive reciprocal effects (70.65), while reciprocal cross SY-200× SW-202 (-30.26) had undesirable reciprocal result (Table 4). Among eight inbred lines four inbred lines depicted positive general combining ability effects with maximum value (0.091) for PH-203 which was considered the best general combiner for number of ears per plant, while the parent JL-205 (-0.09) considered insufficient general combiner among all the genotypes (Table 2). The best specific combinations were PH-203 × SY-204 (0.21) followed by SW-202×IQ-207 (0.18), whereas the cross SY-200×PH-203 showed undesirable result for specific combining ability in case of ears per plant (-0.09).

Among reciprocal crosses twenty four were explored positive effects, maximum reciprocal results were displayed by cross SW-202×PH-203 (0.10), while poor performance was recorded in SY-204×PH-203 (Table 4). Regarding number of kernel rows per ear parental line PH-203 proved to be good general combiner (0.31) followed by SY-204 (0.18), while JL-205 was poorest general combiner due to their maximum negative (-0.56) for number of kernel rows per ear (Table 2). Among cross combinations thirteen crosses were good specific combiners on account of their positive effects. Maximum specific combining ability was depicted by cross SW-202×IQ-207 (1.72). The highest negative value of specific combining ability effect (-0.85) was recorded from single cross PH-203×JL-205 (Table 3). Among the crosses SY-204×IQ-207 (1.01) followed by SY-200×PH-203 (1.00) were important positive reciprocal effects with respect to number of kernel rows per ear (Table 4), however lowest effect (-1.36) was obtained by from reciprocal cross SW-202 ×JL-205. Similar finding in maize were reported by Chandana and Deshpande (2016). In case of number of kernels per row (Table 2) showed that six of the parents had desirable general combining ability results with highest (1.52) for parent SY-200. The parent JL-205 (-2.35) had the maximum negative general combining ability result followed by AZ-201 with value of (-1.49). For number of kernel per rows (Table 3) direct cross SY-200×SW-206 gave highest specific combining ability (3.76), the cross PH-203×SY-204 had negative specific combining ability effect (-1.92). Maximum reciprocal effect was reported in cross SY-204×SW-206 (3.45), while the cross SW-202×SW-206 displayed undesirable reciprocal result (-2.98) (Table 4). The finding by various research workers in maize were in accordance to this study (Mahmood *et al.*, 2019; Kuselan *et al.*, 2017 and Andeera *et al.*, 2019) ^[4, 3, 12]. Five inbred lines had declared general combining ability results in positive direction and remaining three were negative (Table 2). Inbred line SW-202 had the maximum general combining ability effect (0.95), while parent AZ-201 (-1.18) followed by PH-203 (-0.47) exhibited poorest performance for general combining ability for 100-kernel weight. Among the direct cross combinations PH-203×JL-205 showed highest specific combining ability effect (2.90), while cross SY-200×PH-203 (-2.69) was poorest specific

combiner for 100-kernel weight (Table 3). In case of indirect cross combinations AZ-201×SW-202 followed by SY-204×IQ-207 showed highest reciprocal effects (3.12, 2.04), but the cross JL-205×IQ-207 (-1.79) had negative reciprocal effect (Table 4). The results are accordance to the finding of (Alam *et al.*, 2008 and Atif *et al.*, 2012) ^[1, 5]. In case of grain yield per plant (Table 2) six inbred lines showed desirable general combining ability results. While remaining two parents AZ-201 and JL-205 were poor general combiners due their negative effects. Good specific combiners were PH-203×SW-206 (55.73) followed by SY-

200×SW-206 (46.75) for grain yield per plant (Table 3). Reciprocal crosses SW-202×PH-203 followed by SW-202×IQ-205 gave highest reciprocal effects (40.01, 26.33), while the crosses SY-200×IQ-205 (-21.16) and SY-200×PH-203 (-5.23) had undesirable reciprocal results (Table 4). These finding are accordance to Neha *et al.*, (2019) ^[17]. The significance of general combining ability, specific combining ability and reciprocal effects reflected significant contribution of genetic components of variation regarding plant height, leaf area, number of ears per plant, number of kernels per row and 100-kernel weight.

Table 2: Relative general combining ability effects for some polygenic traits in maize

Inbred	Plant height (cm)	Leaf area (cm ²)	Ears per plant	Kernel per row	Number of kernels per row	100-kernel weight (g)	Grain yield per plant (g)
SY-200	5.31	3.29	0.08	0.61	1.52	0.63	1.44
AZ-201	-1.80	-12.25	-0.02	-0.63	-1.49	-1.18	-21.10
SW-202	4.60	20.11	-0.07	0.47	0.72	0.95	6.14
PH-203	-0.42	1.90	0.09	-0.02	0.56	-0.47	8.82
SY-204	-1.23	16.38	0.04	0.20	0.55	0.57	12.07
JL-205	-2.02	-37.01	-0.09	-0.92	-2.35	-1.31	-22.75
IQ-207	-4.25	11.94	0.01	-0.05	0.21	0.70	10.26
SW-206	-0.17	-4.35	-0.02	0.43	0.26	0.09	5.09

Gene action

Assessment of genetic diversity among maize genotypes (Table 5) expressed greater differences for general, specific and reciprocal effects depicting the existing of additive and non-additive genetic effects. The variance components for plant height due general combining ability (gca) were -3.98 % of the total variance. While components of variation due specific combining ability (sca) and reciprocal effects were 127.91 and 34.22 % respectively for the total variance. Hence it is concluded that non-additive genetic effect were more important for plant height. Amiruzzaman *et al.*, (2013) ^[2] concluded that plant height was controlled by both additive and non-additive genetic effects. While Neha *et al.*, (2018) ^[17] estimated that plant height was under the control of non-additive type of gene action. The variance for leaf area due general combining ability was 147.80 % and value of specific combining ability (1354.05 %) and reciprocal (423.31 %) of the total variance. Specific combining ability contribution more which were due to non-additive type of gene action. In case of ears per plant, the components of variation due to general combining ability and specific combining ability were 6.26 % and 2.49 % respectively. The ratio of gca/sca is more than 1, so the trait was under the control of additive type of gene action. Accordance to Taufiq and Ijaz (2016) ^[21] both additive and non-additive genetic effects were important for number of ears per plant. Regarding kernel rows per ear, the estimation of genetic

components of variation (Table 5) displayed maximum general combining ability as compared to specific combining ability differences; the ratio of gca/sca was 3.00 % which is indicating additive type of gene action. The same finding was also reported by Asif *et al.*, (2020) ^[4]; Atif *et al.*, (2012) ^[5]; Kabdal *et al.*, (2003) ^[11]; Masood *et al.*, (2020) ^[13] and Nazir *et al.*, (2020) ^[16] and for kernel rows per ear in maize. Assessment of genetic analysis for number of kernels per row (Table 5) depicted the general combining ability to specific combining ability variance ration (gca/sca) was 0.27, indicating the non-additive genes influence. Kuselan *et al.*, (2017) exposed that both additive and non-additive genetic effects were involved in the manifestation of this trait. For 100-kernel weight the genetic component of variation (Table 5) showed a greater SCA variance (σ^2_s) as compared to GCA variance (σ^2_g) enlightening the prevalence of non-additive genes effects. In case of kernel yield per plant the variance component for general, specific combining ability and reciprocal effects were (95.71, 885.73 %) and 168.67 % respectively, of the total variance which indicate non-additive type of gene action was more important for the inheritance of this trait. The results were in agreement with the finding of Danish *et al.*, (2020) ^[8]; Neha *et al.*, (2018) ^[17] and Yaqoob *et al.*, (2020) ^[22]. The variation may be due to different sources of genetic materials and the environment under which study was carried.

Table 3: Relative specific combining ability effects for some polygenic traits in maize.

Direct crosses	Plant height (cm)	Leaf area (cm ²)	Ears per plant	Kernel rows per ear	No. of kernels per row	100-kernel weight (g)	Grain yield per plant (g)
SY-200 × AZ-201	7.875	48.11	-0.02	-0.14	1.01	0.73	-4.69
SY-200 × SW-202	-0.51	-12.04	-0.08	-0.10	-0.87	-0.78	-38.04
SY-200 × PH-203	3.90	25.54	-0.07	-0.22	-0.56	-2.69	-21.69
SY-200 × SY-204	-0.94	48.80	0.17	1.56	2.52	2.83	41.63
SY-200 × JL-205	5.98	-55.03	0.09	-0.35	-1.86	-0.75	0.51
SY-200 × IQ-207	5.63	3.79	0.07	-0.89	-0.81	2.61	-13.36
SY-200 × SW-206	4.41	12.65	0.04	0.89	3.76	2.44	46.75
AZ-201 × SW-202	7.33	5.81	-0.03	0.14	-0.71	-0.73	5.98
AZ-201 × PH-203	3.01	15.94	-0.03	1.35	0.61	-1.61	-10.76

AZ-201×SY-204	6.77	3.87	-0.06	0.14	0.73	1.22	-5.39
AZ-201×JL-205	6.23	-31.07	0.05	-0.43	0.70	0.96	9.96
AZ-201×IQ-207	-3.28	-27.03	0.07	0.35	-0.88	0.25	-18.71
AZ-201×SW-206	13.65	20.91	0.04	-0.52	-1.19	1.61	13.44
SW-203×PH-203	5.66	28.07	0.17	0.39	2.86	2.88	24.19
SW-203×SY-204	-6.13	-3.58	-0.09	-0.14	-1.79	1.63	-18.44
SW-203×JL-205	6.37	34.66	-0.03	-0.06	-0.81	1.37	5.33
SW-203×IQ-207	5.77	30.88	0.18	1.72	1.38	0.02	47.01
SW-203×SW-206	5.19	7.87	-0.04	-0.47	0.43	-0.42	-26.54
PH-203×SY-204	5.89	-4.32	0.21	-0.61	-1.92	-1.18	-24.47
PH-203×JL-205	-2.62	-62.84	-0.06	-0.85	-1.00	2.90	-15.94
PH-203×IQ-207	3.15	37.93	-0.03	0.60	3.45	2.58	28.54
PH-203×SW-206	-1.69	14.61	0.07	0.39	1.80	1.94	55.73
SY-204×JL-205	8.89	11.511	-0.06	-0.06	1.62	-1.22	-3.49
SY-204×IQ-207	6.47	9.06	-0.02	-0.60	2.07	-0.33	40.57
SY-204×SW-206	-4.66	6.61	-0.04	0.52	1.00	0.18	2.41
JL-205×IQ-207	-1.95	38.58	0.01	0.47	-0.01	-1.60	-14.03
JL-205×SW-206	1.96	34.43	-0.04	0.60	1.99	-0.01	4.64
IQ-207×SW-206	3.10	-2.54	-0.04	-0.60	-2.17	-1.22	-43.94

Table 4: Relative reciprocal effects for some polygenic traits in maize.

Reciprocal Crosses	Plant height (cm)	Leaf area (cm ²)	Ears per plant	Kernel rows per ear	No. of kernels per row	100-kernel weight (g)	Grain yield per plant (g)
AZ-201 × SY-200	3.78	-1.66	0.02	-0.33	-1.59	-0.69	5.43
SW-202 × SY-200	-2.56	-30.26	0.03	0.67	-1.16	-0.19	1.93
PH-203 × SY-200	3.71	-28.51	0.08	0.68	-0.19	-0.31	-5.23
SY-204 × SY-200	3.03	19.58	0.27	1.00	0.84	0.87	21.18
JL-205 × SY-200	3.23	70.65	-0.02	0.38	1.23	0.92	10.56
IQ-207×SY-200	0.08	4.20	0.07	0.34	1.12	0.68	-21.16
SW-206×SY-200	1.31	-10.96	0.09	0.65	1.89	0.30	20.25
SW-202×AZ-201	-1.13	-4.21	0.03	0.67	-2.51	3.12	12.78
PH-203×AZ-201	-13.65	7.53	0.07	0.07	0.24	0.63	5.28
SY-204×AZ-201	-8.43	8.11	0.03	0.09	1.12	1.88	3.30
JL-205×AZ-201	-6.43	72.53	0.01	-0.86	0.26	1.80	0.18
IQ-207×AZ-201	11.98	23.39	-0.07	0.03	0.16	0.10	0.67
SW-206×AZ-201	-0.03	30.98	0.05	0.93	-0.35	0.62	2.36
PH-203×SW-203	2.133	16.73	0.10	0.62	1.40	1.52	40.01
SY-204×SW-203	10.06	12.65	0.09	0.69	0.18	1.23	9.90
JL-205×SW-203	2.01	5.33	0.03	-0.69	-1.03	-0.31	7.95
IQ-207×SW-203	4.55	16.61	0.09	0.37	0.90	0.39	26.33
SW-206×SW-203	-3.78	12.00	0.04	0.67	-2.98	0.16	3.48
SY-204×PH-203	6.00	1.33	-0.08	-1.00	0.02	0.03	7.68
JL-205×PH-203	8.65	51.28	0.07	0.08	-0.06	-0.54	5.25
IQ-207×PH-203	2.56	14.45	0.06	0.66	0.95	1.04	23.51
SW-206×PH-203	-8.46	24.00	0.09	0.38	2.21	0.23	3.21
JL-205×SY-204	-5.50	28.88	0.07	0.07	-0.04	0.38	7.65
IQ-207×SY-204	8.05	32.76	0.08	0.62	3.11	2.04	9.60
SW-206×SY-204	8.61	30.01	0.04	1.00	3.46	0.96	4.88
IQ-207×JL-205	-2.18	8.58	0.03	0.31	0.07	-1.79	1.90
SW-206×JL-205	-1.05	-6.00	0.04	0.36	-0.60	1.10	5.28
SW-206×IQ-207	12.66	-1.01	0.09	0.33	0.80	1.03	4.26

Table 5: Estimates of genotypic variances for general (gca), specific (sca) and reciprocal effects for some quantitative traits in maize

Traits	σ ² g	σ ² s	σ ² r	σ ² g/σ ² s ratio
Plant height (cm)	-3.98	127.91	34.22	-0.03
Leaf area (cm ²)	147.80	1354.05	423.31	0.10
Ears per plant	6.26	2.49	4.06	2.51
Kernel rows per ears	1.27	0.42	8.48	3.00
Kernels per row	1.05	3.78	0.87	0.27
100-kernel weight (g)	0.22	4.45	0.66	0.04
Grain yield per plant (g)	95.71	885.73	168.67	0.10

σ²g = GCA variance, σ²s = SCA variance, σ²r = reciprocal variance.

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